UNITED STATES AIR FORCE MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

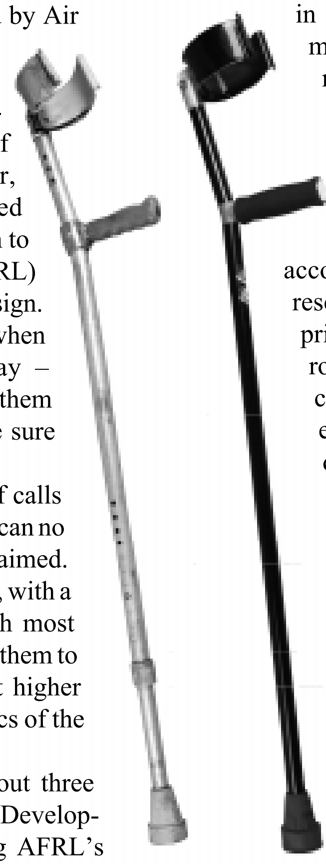
Materials & Manufacturing Directorate

Wright-Patterson Air Force Base • Dayton, Ohio **Summer 2000**

Aerospace Composite Material Provides Lightweight Alternative for Forearm Crutches

By Sue Baker
ASC Public Affairs

"Strong as a rock and light as a feather" are the words Jim Barone uses to describe his new, forearm crutches — 60 percent lighter, 20 percent stronger, and 90 percent quieter than conventional aluminum crutches — and the first in the world crafted entirely of Carbon Fiber-Reinforced Polymer (CFRP), a material originally developed by Air Force researchers here in the early 1970's for military air and space applications.



"They are incredibly light, yet feel rock-solid," said Barone, executive director of the Sacramento Air Logistics Center, McClellan AFB, Calif., who has used crutches for 45 years, and is testing them to help Air Force Research Laboratory (AFRL) scientists assess the benefits of the new design. "Just a few ounces make a big difference when you are carrying them around all day – constantly picking them up, swinging them around, and maneuvering them to make sure they don't slip."

"They are amazingly quiet – my staff calls them the 'stealth' crutches, because they can no longer hear me coming!" Barone exclaimed. "And they look so good – sleek and clean, with a black, painted finish that blends in with most clothing – that my wife wants me to wear them to our daughter's wedding in May. What higher compliment could be paid to the aesthetics of the design?"

The new crutch design was born about three years ago, as a Cooperative Research and Development Agreement (CRDA) effort among AFRL's Materials and Manufacturing Directorate; Ergonomics, Inc., a Dayton firm specializing in superior ambulatory aids, crutches, canes, and walkers; and the Wright Technology Network, which promotes government-business partnerships and opportunities across Ohio.

"Design and materials for forearm crutches, typically used by individuals with disabilities in their lower extremities, date back to the 1920's," said Dr. Steve Donaldson, AFRL materials research engineer. "Current crutches are heavy, weighing about five pounds per pair. And in time, they become terribly noisy.

"Conventional aluminum crutches have a double, telescoping design that is adjusted to individual height using spring-loaded pins, which pop out into the holes in the outer tube," said the doctor. "In a short time, these holes elongate, allowing motion between the pin and the hole — and lots of noise, which most crutch-users would love to eliminate."

Another drawback to current crutch designs: they wear out too fast. "Most users replace their crutches, which range in cost from $60 to $160, at intervals between two months and a year," Dr. Donaldson said. "And all-metal designs typically have an institutional, medical look — all these concerns may not be much of an issue for a short-term user, but may degrade the quality of life for those who have to use them on a long-term basis."

Advantages of the new design are many, according to Dr. Vernon Bechel, AFRL materials research engineer assisting Dr. Donaldson. "The primary, load-bearing tubes of the new crutches, table-rolled from graphite/epoxy prepreg and thermally cured, can now be purchased commercially, " he explained. "The central intersection fitting, though die-cast from aluminum, has three protruding tubes over which the composite tubes slide, and to which they are bonded with aerospace grade structural adhesive. This part is designed so that in the rare event the hand grip is overloaded, the aluminum will yield before the composite tube breaks, clearly indicating to the user that the crutch should be replaced."

And the fitting advantages of the new crutch are many for future, potential users, according to Dr. Donaldson. "Anyone located anywhere in the world would only need to provide two dimensions — the distance between the end of the rubber foot and the handle; and from the handle to the middle of the cuff – via fax or e-mail to the manufacturer," he said. "The manufacturer could then pull two, pre-fabricated composite tubes from stock; cut them into three, measured pieces; bond the pieces together with adhesive; cure them; add the last few parts (rubber foot, cuff and foam grip); and ship to the customer."

Joyce Young, president of Ergonomics, Inc., started in 1993, said her company first became involved with the project through Wright Technology Network, which helped her investigate production sources.

"The new, all-composite crutches will be custom-made, and will go into production as the orders come in," Young explained.

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Materials R&D Success Stories

Computed Tomography Support Assists Development Of Composite Heat Exchangers For Multi-Service Program

High-temperature, low-weight, compact, carbon-carbon composite heat exchangers for existing and next generation combat aircraft are being designed and developed by the Air Force Research Laboratory (AFRL) Air Vehicles Directorate (VA).

AFRL's Materials and Manufacturing Directorate (ML) provided the computed tomography which solved the critical problems of viewing and analyzing the internal structure of these heat exchangers during prototype development.

Heat exchangers are a critical part of Air Force weapon systems, providing thermal management for on-aircraft environmental control systems. Since heat exchangers typically make up nearly half the weight of these systems, saving weight can add significantly to the mission capability of combat aircraft.

A program sponsored by VA is underway to develop a rugged, lightweight, high-temperature carbon-carbon (C-C) composite heat exchanger for next-generation and existing thermal management systems. Two different assembly methods are under consideration. Conventional processing involves making C-C plates and fins, then brazing all joints to form the core, a method similar to making a metal heat exchanger. Integral processing involves co-processing C-C fins and plates, then joining these structures by brazing. In either case, the joint bond is the most critical part of the construction.

VA needed to evaluate both these processes to determine the percent fill and quality of braze bonding. Many examinations and tests were to be performed on the composite heat exchangers to determine quality of process and performance specifications for the resulting part. Most of these tests required the destruction of the test part to examine its internal structures. Only computed tomography (CT), a nondestructive evaluation (NDE) test method, offers the capability to examine the internal structure of a test part as it will actually appear in use, revealing invaluable data about the internal structures of the part under investigation. CT was also selected to study the quality control of the heat exchanger manufacturing process, thereby indicating whether the process could reduce risk to an acceptable level to establish a possible manufacturing technology program.

F-22 Raptor is one weapon system that can benefit from carbon-carbon heat exchangers.

The X-Ray Computed Tomography Facility at ML was selected to conduct NDE investigations. The first prototype coupon tested was the original conventional assembly design, made of C-C composite. Analysis of the CT image revealed that only minimal braze bonding had occurred, with an estimate of 20 percent fill. With this data in hand, the manufacturing process was adjusted and a second prototype coupon was fabricated and subjected to CT examination. Analysis of the second image showed an estimated 80 percent braze bonding, a significant improvement in the manufacturing process.

Because the CT image provided otherwise-unobtainable process information, this NDE technique was also used on the prototype coupon that was prepared using the integral processing assembly. This contained a completely integral, processed carbon-bonded single flow layer, including a silicon carbide (SiC) oxidation protective coating. Analysis of this image revealed a complete carbon bond between corrugation fins and the plate prior to brazing, as well as the level of the SiC coating layer.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 99-539.

CALENDAR OF EVENTS

Materials & Manufacturing Directorate
Roadmap Review
July 11-13, 2000
Dayton, OH

Materials, Manufacturing & Enabling
Technologies Series
July 13, 2000 - Dayton, OH

Laser Hardened Materials Program Review
August 22-24, 2000
Boulder, CO

International Conference on Fatigue Damage
of Structural Materials III
September 18-22, 2000
Hyannis, MA

DoD Composite Repair Workshop
November 13-16, 2000
Coeur d'Alene, ID

New Lightweight Core Material Strengthens Aerospace Structures

A unique partnership involving Air Force Research Laboratory's Materials and Manufacturing Directorate (ML), Air Vehicles Directorate (VA) and Armament Directorate (MN) has led to the successful development and transition of a structural sandwich material that's stronger and more cost effective than traditional core materials.

Pioneered by WebCore Technologies, Inc., the new core structure, called TYCOR|, is currently being evaluated for possible use in the Unmanned Combat Air Vehicle (UCAV) and the Joint Air to Surface Standoff Missile (JASSM) programs. It could lead to substantial savings in their fuselage costs, while improving structural reliability.

TYCOR| cores offer superior structural performance, durability, weight savings and cost savings compared to traditional foam core materials, and a high degree of design flexibility using different types of foam, fibers and fabrics. All of these can be tailored to meet the structural requirements and cost target of a sandwich panel application. Made possible through the Air Force Research Laboratory's support, WebCore's unique process integrates porous fiberglass or carbon fiber reinforcements in a three-dimensional truss architecture through the thickness of low-cost, low-density foam to achieve z-directional reinforcement.

TYCOR| fiber reinforced foam (FRF) core materials are designed to be used in liquid molding processes where the porous reinforcements act as resin channels during molding, then co-cure with the skin layers to produce an integrated sandwich panel with improved structural performance. The dry fibers, infused with resin during molding, cure to form the structural members, while the skin attachment features greatly enhance the core-to-skin bonds in the sandwich panel, resulting in high strength and excellent damage tolerance capability. The fibers making up the reinforcing members are mechanically tied with the sandwich panel skins, helping to eliminate skin-to-core delamination.

A wide variety of TYCOR| core materials and panels have been fabricated and tested during the research effort using various combinations of foam, fiber, resin and reinforcement architecture. The current prototype machinery can manufacture TYCOR| cores and preforms in the thickness range of one-quarter inch to three inches. Depending on the design variables and choice of materials, the core's density in the molded panel ranges from about six to 18 pounds per cubic foot. The core shear strength ranges from about 150 to 750 pounds per square inch (psi) and the core shear modulus ranges from about 5,000 to 50,000 psi. The compressive strength ranges from approximately 300 to 1,200 psi.

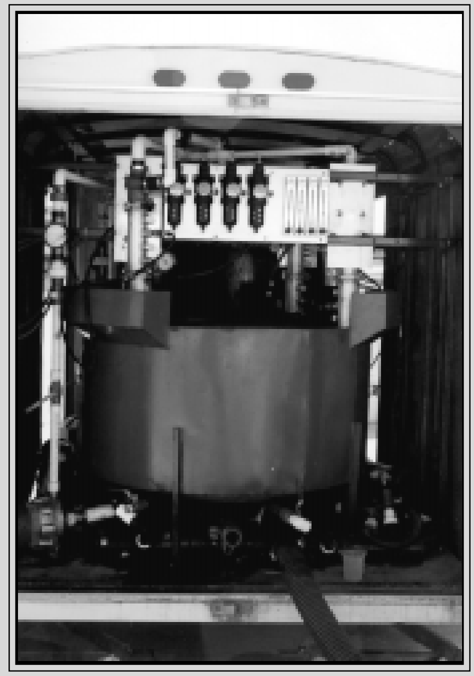
Carbon fiber reinforced TYCOR| panels show excellent fatigue resistance, offering 100 percent strength retention under cyclic flexural loading after one million load cycles at 50 percent of maximum static load. TYCOR| cores and sandwich panels have also exhibited outstanding impact damage tolerance capability. Upon impact, the panels developed visible impact damage on the frontal face but no damage on the opposite face. And, the extent of impact damage in the frontal face and core was limited to the immediate impact area. The compression after impact testing that followed revealed the panels retained about 95 percent of their original strength before impact. TYCOR's superior impact damage tolerance is attributed to inherent "redundant load path" architecture, which results in an ability to contain all the damage within the immediate impact area, as well as its superior skin-to-core attachment characteristics.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 00-005.

Hydrocyclone Reactor Speeds Removal Of Contaminants From Wastewater

A cooperative research effort involving the Air Force Research Laboratory's Materials and Manufacturing Directorate (ML), Advanced Processing Technologies, Inc., and Kemco Systems, Inc., produced a reactor system that removes 80-100 percent of the contaminants found in cleaning and maintenance wastewater streams.

A range of Air Force activities, particularly cleaning and maintenance, generate waste streams containing suspended solids; petroleum, oil and lubricant (POL) products; emulsion stabilizing agents; and aqueous, film-forming foam (AFFF) contaminants. For the past few years, the challenge facing scientists and engineers at the ML Air Expeditionary Forces Technologies Division (MLQ) at Tyndall AFB, Fla., has been to develop an efficient, cost-effective means for removing these contaminants from the wastewater.



The reactor system

Conventional pretreatment processes are either ineffective or too costly for treating emulsified oils caused by soaps, detergents and AFFF releases, while other methods, such as thermal treatment, chemical demulsification, depth filtration and combinations of these, are expensive and usually have high operation and maintenance costs.

This Small Business Innovation Research (SBIR) project sought an efficient, cost-effective approach for removing emulsified oil, fuel and grease from aircraft wash rack wastewater containing detergents, and removal of AFFF from fire fighting wastewater. The continuing SBIR Phase II work emphasized on-site, pilot-scale tests using a trailer-mounted, mobile air-sparged hydrocyclone (ASH) technology unit modified from lessons learned during Phase I testing. The reactor consists of a cyclone in which pressurized air and wastewater are introduced to maximize air-to-particle interaction. Attachment of air bubbles to contaminants is achieved for removal of hydrophobic particles or oil droplets. Contaminants are then separated from the bulk liquid phase and the clean water is discharged.

These tests have been completed at five Air Force bases. The results confirm that ASH technology is capable of removing oil and grease, oily solids and AFFF from wastewater streams efficiently, and at a low cost; only $0.40-1.10 per 1,000 gallons, depending on the waste stream being treated. The results also showed the system processes up to 20 gallons of wastewater per minute, a capacity 100-500 times that of any existing conventional equipment. At that rate, each liter of wastewater is inside the reactor (2.0 inches inside diameter and 24 inches long) for less than 0.25 seconds.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 00-081.

(Crutch continued from page 1)

definitely looking at a world-wide market.

"The cost per pair has yet to be determined, but will be about $600," Young said. "We have discussed local production capabilities with the National Composite Center and Goodwill Industries, but at this point, we cannot estimate the number of jobs this will create here in the Miami Valley."

Ergonomic's technology agreement with AFRL is typical of most CRADA activities, with five percent of the gross sales of the new crutch design to be returned each year to the laboratory, according to Young.

COMPLETED CONTRACTS

- Novel Pulsed Molecular Ion Source For Realtime Gallium Nitride Thin Film - F33615-97-C-1035
- Manufacturing 2000: Automotive Components And Sheet Metal Parts - F33615-94-C-4428
- Manufacturing 2005: Communication In The Aerospace Industry - F33615-94-C-4429
- Environmentally Compliant, No Volatile Organic Compound Aircraft Coating - F33615-97-C-5003
- Novel Transparent Coating For Canopy Electrostatic Discharge Protection - F33615-99-C-5006
- Reduced Dimensional Variation Of Organic Matrix Composite Lay Ups - F33615-97-C-5007
- Innovative Coatings For High Reliability Microelectromechanical Systems - F33615-99-C-5007
- Oxidation Resistant Carbon Matrix Composites - F33615-99-C-5008
- High Temperature Seal Development - F33615-94-C-5009
- Novel Composites For Microelectronic Packaging Applications - F33615-99-C-5012
- A Durable Primer For Aircraft Applications - F33615-99-C-5013
- Thermal Control Coatings For High Thermal Conductivity Substrates - F33615-95-C-5028
- Advanced Performance Coating Degradation Mechanisms - F33615-98-C-5033
- 3-D Strength Prediction Of Composite Materials - F33615-95-C-5041
- Processible Conductive Resin For High Temperature Applications - F33615-97-C-5090
- Integrated Knowledge Environment - Integrated Product Management - F33615-96-C-5109
- Electronics Computer Assisted Design-Computer Assisted Manufacturing Exchange - F33615-96-C-5118
- Electronic Component Information Exchange - F33615-97-2-5121
- Radiography For Aerospace Applications - F33615-97-C-5122
- Net Shape Casting Production Machine - F33615-97-C-5123
- Dynamic Polymer Composite Connectors For Affordable Composite Structure - F33615-97-C-5126
- Mechanical Behavior Of Advanced Aerospace Materials - F33615-94-C-5200
- Deformation Process Modeling Of Discontinuously Reinforced Aluminum Extrusions - F33615-98-C-5212
- Probabilistic Micromechanical Fatigue Model - F33615-99-C-5213
- Advanced Nondestructive Inspection Technique For Agile Manufacturing - F33615-95-2-5239
- Advanced Laser Ultrasonic Receiver For Low Cost Inspection - F33615-95-2-5245
- Advanced Resin System For Resin Transfer Molding/Vacuum Assisted Resin Transfer Molding Processing - F33615-99-C-5311
- Efficient Processing Of Titanium Aluminides - F33615-93-C-5312
- A Non-Invasive Vibration Sensor For The Machine Shop - F33615-99-C-5312
- Environmentally Compliant Coatings - F33615-93-C-5357
- Highly Anti-Reflective Surfaces For Infrared Semi-Conductor Materials - F33615-99-C-5406
- Development Of High Anti-Reflective Surfaces For Semiconductors - F33615-99-C-5407
- Next Generation Narrow Band Absorbers For Laser Eye Protection - F33615-99-C-5409
- Gate Oxide Screening Methodology And Surface Smoothing - F33615-99-C-5411
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- Nano-Engineered Magnetic Materials For High Temperatures - F33615-99-C-5420
- Electrostatic Self-Assembled Nonlinear Optical Thin Films - F33615-99-C-5422
- Growth Of Bulk Ternary Indium Phosphide Arsenide Single Crystal Alloys For Opto-Electric Applications - F33615-96-C-5464
- Enhanced Sensor Modules - IV - F33615-96-C-5471
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- Reasoning In 3 Dimensions: A Common Framework For Design, Manufacture And Tactical Planning - F33615-95-C-5560
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- Low Temperature Compression Set Resistant O- Ring - F33615-99-C-5605
- Development Of Static Dissipative Hard Laminate - F33615-99-C-5606
- Development Of Static Dissipative Hard Laminate SurfaceS - F33615-99-C-5607
- Optical Measurement Facility (On-Site) - F33615-89-C-5608
- A Collaboration Optimization - F33615-96-C-5613
- Novel Low Cost Thermosets For Advanced Aerospace Composites - F33615-96-C-5628
- Enhanced Pultruded Composite Materials - F33615-96-C-5629
- Web-Based Collaborative Environment With Knowledge Driven Agents - F33615-99-C-5705
- Technical Operations Support - I - F33615-94-C-5800
- Web-Based Collaborative Warfighting Cost Per Flying Hour - F33615-99-C-5904

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